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PUBLIC HEALTH ASPECTS OF THE CONTAMINATION OF GROUND WATER IN SOUTH PLATTE RIVER BASIN IN VICINITY OF HENDERSON, COLORADO, AUGUST, 1959

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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by

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The health hazard resulting from present or future use of contaminated ground water for drinking and culinary purposes is examined in this study. It includes a limited survey of private domestic wells in the area and considers the possible contamination of wells supplying the city of Brighton. It is concluded that a portion of the shallow ground water aquifer in the area between Derby and Henderson is contaminated, and that wastes discharged from the Rocky Mountain Arsenal from 1943-1955 are the principal source of such contamination. Sludge, may also be a source of continuing contamination.

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PUBLIC HEALTH ASPECTS OF THE CONTAMINATION OF GROUND WATER IN SOUTH PLATTE RIVER BASIN IN VICINITY OF HENDERSON, COLORADO, AUGUST, 1959

INTRODUCTION

A preliminary study of the public health aspects of contamination of the ground water in the South Platte River basin between Derby and Henderson, Colorado was made during August 10-21, 1959. This study was undertaken at the request of Governor Stephan L. R. McNichols; Dr. Roy L. Cleere, Director, State Department of Health; and Representative Byron L. Johnson, all of Colorado. Representatives of the Army Chemical Corps, including personnel at the Rocky Mountain Arsenal, cooperated in providing assistance and information. The Public Health Service Regional Office in Denver assisted in making the arrangements and plans for the field survey.

This study was limited to the review of reports and other information on the problem; to consultation with personnel of the Rocky Mountain Arsenal, the State and Tricounty Departments of Health, the U. S. Geological Survey, and the University of Colorado; to the inspection and review of waste disposal facilities

at the Rocky Mountain Arsenal and at each of five oil refineries; and to interviews with various individuals who are concerned with this problem.

In contrast to previous studies which have emphasized the possible damage to crops due to use of contaminated ground water for irrigation, this study undertakes to evaluate the health hazard resulting from present or future use of contaminated ground water for drinking and culinary purposes. It includes a limited survey of private domestic wells in the area and considers the possible contamination of wells supplying the city of Brighton.

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

From the available information, particularly the reports prepared by the U. S. Geological Survey and the University of Colorado, it is concluded that a portion of the shallow ground water aquifer in the area between Derby and Henderson is contaminated, and that wastes discharged from the Rocky Mountain Arsenal throughout the period 1943 to 1955 are the principal source of such contamination. Furthermore, sludge, which accumulated in the holding pond used during that period, may be a source of continuing contamination.

Damage to crops irrigated with shallow well water, which was reported to have occurred at the Nesom farm in 1951, was the first evidence of contamination of the ground water. Apparently it had taken 7 to 8 years for the contaminated water to travel approximately 3 miles from the original waste holding

pond. By 1958, ground water contamination extended throughout an area of several square miles. It will continue to be a problem in portions of this and adjacent areas for many years. The serious nature of this contamination should be recognized as one requiring early action.

Those contaminants which have been detected include chlorides, chlorates, and a second phytotoxic substance, which is believed to be 2, 4-D. The possible presence of still other contaminates must be considered.

Available information is that there have been no authenticated cases of illness in the area which can be attributed to the contaminated water. However, the consumption of water over a period of 2 or 3 months containing appreciable amounts of one of these contaminants could adversely affect an individual's health. Tentative maximum permissible limits for drinking and culinary water have been suggested by the Public Health Service. These are 5 mg/l for 2, 4-D and 5 mg/l for chlorates. Additional studies are needed to confirm the limit suggested for chlorates. It should be recognized that permissible limits are aimed at protecting the more susceptible individuals and that the average person might consume water containing somewhat higher concentrations without injury to health.

The area in which the shallow ground water was suspected of having become contaminated as of January, 1958 is indicated in Figure 2. That area outside the Rocky Mountain Arsenal property includes a substantial part of sections 4, 9, 10, 15, 16, 21 and 22, and small portions of other adjoining sections.

In view of the probable existence of contamination of certain private domestic water supplies obtained from shallow wells within the suspected area and the possible eventual contamination of Brighton's shallow well supply, it is recommended that immediate steps be taken to:

1. Determine the present boundaries of the area of shallow ground water contamination.
2. Examine all domestic water supplies obtained from wells within the area contaminated.
3. Provide written notice that water is "unsafe" to householders whose domestic water supply has been found to be contaminated.
4. Undertake studies of the waste and more heavily contaminated well waters in an attempt to detect unknown substances which would be of concern if present in the domestic water supplies within the contaminated area.
5. Make periodic studies to determine the course and rate of flow of the contaminated ground water, and to anticipate what, if any, effect it may have on the Brighton water supply.
6. Determine whether the sludge deposits in Reservoir A still contribute to the contamination, and, if so, undertake corrective measures.
7. Locate and plug any deep wells which provide interconnection between shallow and artesian aquifers within the contaminated area.

8. Undertake toxicological studies to better establish the maximum permissible limit of chlorates in potable water. (Previous concern over chlorates in water, together with that resulting from this incident of ground water contamination, has led to a study of chlorate toxicity now underway at the Robert A. Taft Sanitary Engineering Center.)
9. Monitor the waste evaporation pond in an effort to detect any leakage should it occur.
10. Secure approval of State Department of Health prior to the drilling of a deep injection well.
11. Keep State and Tricounty Departments of Health informed of situation.
12. Hold conferences of those concerned to review the situation and plan future action. One such conference should be held as soon as more adequate information becomes available on the extent of the area of contaminated ground water, and the various contaminants and concentrations present. At least one conference should be held each year as long as the problem continues to be of concern.

It is recommended that the Chemical Corps establish a time schedule for the various steps in the monitoring program and other control measures.

AREA UNDER CONSIDERATION

GEOGRAPHY

The total area considered in this study covers approximately 60 square miles in the South Platte River basin between Derby and Brighton, Colorado. This area is in southwest Adams County which is adjacent to and northeast of Denver, Colorado (See Fig. 1).

The U. S. Geological Survey (1) has characterized this area as one having broad, rolling hills of low relief in the east that slope gently westward to broad, flat terraces that border the South Platte River. The Slopes range from 20 to 50 feet per mile.

Near the southern boundary of the area Sand Creek flows toward the northwest. This creek receives effluents from the Aurora and one of the City of Denver's sewage plants, also more or less treated wastes from two oil refineries. First Creek flows in a northwestwardly direction across the middle of the area. Its flow is intermittent upstream from the point where the effluent from the Rocky Mountain Arsenal sewage treatment plant enters. Second and Third Creeks also traverse the area near its northeast boundary.

The Burlington and Fulton ditches and the O'Brian Canal, which at times contain water consisting to a large extent of partially treated sewage from the Denver Treatment Plant, traverse the area. Water from these ditches and canals is used for irrigation purposes.

GEOLOGY

The U. S. Geological Survey (1) describes the geological formation as follows:

> "The report area is underlain by Quaternary sediments, which rest on irregular bedrock of Tertiary age. The bedrock consists of weathered buff to gray sand shale that grades into hard gray shale. The overlying sediments include dune sand, terrace deposits, and alluvium ranging in thickness from a few feet to as much as 100 feet. The alluvium and terrace deposits consist of poorly sorted stream-laid deposits of fine to coarse sand and gravel interbedded with lenses of silt and clay. The deposits of sand and gravel are dominantly granitic and generally reddish brown. Eastward, on the high ground above the river terraces, the alluvium is overlain by several feet of wind-blown sand."

The above-noted U. S. Geological Survey report contains a map showing bedrock contours based on depth to bedrock obtained from logs of wells and test holes and on land surface elevations taken from topographic maps or determined by instrumental leveling. In general the bedrock conforms with that of the land surface in that it slopes downward 20 to 50 feed to the mile toward the South Platte River where it forms a rather restricted channel in the vicinity of Hazeltine and Henderson. Extension of these bedrock contours to include the northwest portion of the area past Brighton might provide valuable information.

DOMESTIC WATER SUPPLIES

Throughout much of the area each dwelling is provided water from its individual well. In a few cases two or more dwellings are supplied water from a single well. Water is obtainable from the shallow aquifer in large quantities. Such water is very hard. It is used extensively for irrigation and in a few instances for domestic water supplies. Limited quanti-

ties of soft water are obtainable from the deeper artesian aquifers. Where economic considerations have not been a prime factor most dwellings utilize a deep well domestic water supply.

An exception is the City of Brighton which secures the water from 12 shallow wells. In this case it would be impractical to obtain the required quantity from deep artesian wells.

POSSIBLE SOURCES OF CONTAMINATION

Rocky Mountain Arsenal

The Rocky Mountain Arsenal, a military reservation operated by the Chemical Corps, is located immediately north of Stapleton Municipal Airport, Denver. Reportedly it was utilized starting in 1943 for several years in the manufacture of chemical warfare agents. More recently the industrial facilities have been leased to the Shell Oil Company, which has used them to manufacture insecticides.

From 1943 through September, 1955 wastes from the manufacture of various chemicals were discharged to Reservoir A, a natural holding pond. During part of this period wastes from a chlorine processing plant were discharged to Reservoir C. Since early October, 1955 all industrial wastes are reported to have been discharged either directly, or indirectly into the 96 acre evaporation Reservoir F, which is lined with approximately $\frac{1}{2}$ inch thick asphalt membrane to prevent seepage of waste water into the ground.

Oil Refineries

Continental Oil Company

According to H. J. Dillard, Chief Chemist, the Conoco Refinery was constructed around 1929. Wastes were discharged without treatment prior to 1947 when an API oil separator was constructed. In 1958 a biological oxidation plant was placed in operation to treat the phenolic and sulfide wastes. These facilities also include a skimming and settling tank. The biological treatment and dilution by other waste water is reported to reduce phenol from around 500 to 4 or 5 mg/l, and sulfides from about 250 to 4 or 5 mg/l.

The facilities appeared to be properly maintained and well operated. The treated wastes are discharged to the Burlington ditch.

Bay Oil Company

Information obtained from Robert Kelly, Assistant Chemist, is that the Bay Oil Company Refinery has been in operation since about 1937. Originally no treatment was given to the wastes, but sometime around 1953 an API oil separator tank was installed. The treated wastes are discharged into Sand Creek.

Skelly Oil Company

The Skelly Oil Company waste disposal facilities were inspected in company with Howard Masters, Manager. The refinery has been in operation since around 1934. The first waste treatment facilities were installed around 1953. These consist of two earthen pits operating in series, each with a submerged

outlet, and a relatively small holding pit excavated into the alluvium.

Empire Oil Refinery

An inspection of the Empire Refinery waste disposal facilities was made in company with L. R. Cox, Vice President in Charge of Refinery. This refinery commenced operation around 1939. It produces asphalts as well as the usual gasoline, intermediates, and fuel oil products. An API oil separator and a small lagoon were constructed around 1953 to treat the wastes. Treated wastes are discharged to Sand Creek.

Oriental Refinery

The Oriental Refinery is a non-cracking gasoline, diesel fuel, and residual produce operation. Large quantities of cooling water are used. These are discharged without treatment onto the flats approximately 1/4 mile from Sand Creek.

Tank Farms

Based on interviews with W. A. Hart, Assistant Chief Clerk, Phillips Oil Company; E. O. Mill, District Sales Manager, Shamrock Oil Company; and J. L. East, Office Manager, Wyoming-Colorado Oil Company, none of these tank farms had experienced losses, and none handled weedicides.

Sewage Contaminated Water

The detection of alkyl benzene sulfonate in a sample of the Town and Country well(2) and the observance of foam on well water tanks at the Conoco and Empire Oil refineries are indications of sewage contamination of the ground water. Certainly the

presence of sewage polluted waters in the Burlington and Fulton ditches, the O'Brian Canal, and Sand and Second Creeks, and the use of such waters for irrigation, provide ample opportunity for contamination of the ground water.

HISTORY OF CONTAMINATION OF GROUND WATER

Available information indicates that there have been three separate incidents of contamination of ground water in the area. One is the ABS contamination of the Town and Country community well in Derby. Another involved gasoline contamination of a private well in Commercetown. The third is the contamination of the shallow ground water in the area immediately northwest of the Rocky Mountain Arsenal property.

AREA OF CONCERN

The report is primarily concerned with the contamination existing in the shallow ground water in the area northwest and adjacent to the Rocky Mountain Arsenal, and with those areas into which the contaminated water may move (See Fig. 2). It includes consideration of the extension of the area currently contaminated and the downstream movement of the contaminated water in the South Platte River basin.

BACKGROUND INFORMATION

The first indication that the ground water had become contaminated was the report of damages to crops irrigated with shallow well water. Such crop damage was reported to have been observed first at the Nesom farm in 1951, and then at the

Powers and Munson farms in 1952 and at the Yamamoto and Miller farms in 1953. Reported symptoms included yellowing, retardation of growth, or killing of sugar beets, corn, and other crops and pasture grasses.

Complaints and subsequent claims for damages led to the Chemical Corps contracting with the Ralph M. Parsons Company, in May, 1955, to investigate methods of reducing the quantity of the industrial wastes and to attempt to determine whether there existed a contaminant in the ground water injurious to crops, and, if so, to recommend corrective measures. This study (3) is reported to have resulted in a substantial reduction in volume of wastes from on-site operations and the complete retention of such wastes starting in October, 1955, first in storage tanks and later in a 96-acre asphalt-lined evaporation reservoir. Another result was that in May, 1956, a contract was signed with the University of Colorado to undertake plant bioassay, chemical and geological studies to determine the identity and cause of the alleged crop damage, its source, and, if possible a means of treatment or removal.

CONTAMINANTS

Contaminants known to be present in certain shallow well waters taken from within the area include chlorides(1) and chlorates.(5) The weedicide, 2, 4-D, is known to be present in wastes in the holding pond(5) and plant bioassay studies indicate it may be present in waters from some of the shallow wells. Still

other contaminants, which are known to have been present in wastes from the Arsenal's operations, include salts of phosphonic acid, fluorides and arsenic.(3)

In 1954-1956 studies reported by the U. S. Geological Survey showed chloride concentrations, which in the normal ground water range around 100 mg/l, exceeded 200 mg/l in shallow well waters collected over a substantial area. Analyses of some of these waters showed chloride contents in excess of 1000 mg/l.

The plant bioassay studies conducted by the University of Colorado eventually led to the detection of chlorates in water from a few of the shallow wells. Concentrations ranged from 0 to more than 20 mg/l and varied greatly in wells in close proximity. These studies indicated that certain well waters contained substances other than chlorates which are injurious to plant growth. This led to the detection of 2, 4-D in the holding pond waters.(5)

As of August, 1959, neither the State nor Tricounty Departments of Health knew of any authenticated cases of illness* attributable to human consumption of contaminated water obtained from within this area. However, it must be recognized that the consumption over a period of 2 or 3 months of water containing

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*A case of illness, with symptons of vomiting and diarrhea, of an individual using water containing 800 mg/l of chlorides from a well in the contaminated area has since been reported by the Tricounty Department of Health.

appreciable amounts of chlorates or 2, 4-D could adversely affect the health of humans. Tentative maximum permissible limits, which have been suggested by Dr. H. E. Stokinger, Chief of Toxicologic Services, Occupational Health Field Headquarters, Public Health Service, after a review of the literature, are 5 mg/l for chlorates and 5 mg/l for 2, 4-D.

Since the available information on the toxicity of chlorates is insufficient to establish a well founded permissible limit, and since the Public Health Service was already concerned over the problem of chlorates resulting from chlorine dioxide treatment of water, the Sanitary Engineering Center is proceeding with studies to provide such additional information as is considered necessary by their toxicologists.

It should be recognized that "permissible limits" are not "toxic limits." Given adequate information the permissible limits are selected to provide practical certainty that injury will not result from consumption of the proposed concentrations of the substance in water. They are designed to protect the more susceptible individuals. Many persons could conceivably consume water containing somewhat higher concentrations without ill effect.

EXTENT OF CONTAMINATED AREA

Previous studies by the U. S. Geological Survey[1] and University of Colorado[4] have established the general area in which the shallow ground water has become contaminated. The U. S. Geological Survey report is based on data collected through

June, 1956. The presence of abnormal concentrations of chlorides in waters from shallow wells was used to indicate the contaminated area. The isochloride line of 200 mg/l is plotted on Figure 2. Shallow ground waters in this area normally contain not more than 100 mg/l of chloride.

For several years The University of Colorado has been studying waters from area wells by plant bioassay procedures. A map prepared by C. T. Walker shows results of these phytotoxic studies through January, 1958. The general area indicated by these data to be contaminated is shown in Figure 2.

The extent of contaminated area as of August, 1959 is unknown. It is understood, however, that the Rocky Mountain Arsenal has underway a study to determine the present area of contamination. For this purpose it is believed that chloride analyses or conductivity tests of water samples should be adequate.

No information is available on the course and rate of flow of the contaminated water arriving in the vicinity of the South Platte River. Some of this water may rise to the surface. Any contaminated ground water reaching this vicinity which does not flow into the river would be expected to move in a northeastwardly direction toward Brighton. The concentration of the chlorides will be reduced by dilution only; those of the chlorates and other substances may or may not be reduced by still other physical, chemical and biological processes.

It is believed that the contaminated water will move in the somewhat restricted underground channel in the vicinity of

Henderson. Whether it will tend to bypass the Brighton wells will depend on hydrologic conditions which are controlled by rates of recharge and withdrawal of ground water. As more information becomes available the advice of the U. S. Geological Survey should be sought on this problem.

SOURCE OF CONTAMINATION

Both the boundaries of the contaminated area and the types of contaminants present would indicate that the principal source has been the wastes discharged by the Rocky Mountain Arsenal operations. The U. S. Geological Survey studies of the extent and movement of the chloride contamination are convincing evidence that waste originating on the arsenal property have moved to the off-site area which has become contaminated. The map showing the results of the University of Colorado plant bioassay studies provides supporting evidence.

Except for the Rocky Mountain Arsenal wastes, there are no known sources from which chlorates could have originated. No attempt has been made to detect those contaminants--phenols and refined petroleum products--associated with wastes from oil refineries or tank farms, and it is doubtful if such contaminants are present in the ground waters from this area.

DOMESTIC WATER SUPPLIES

There are an estimated 150 residences within the known or suspected area of contaminated shallow ground water. Visits

to approximately 50 homes resulted in obtaining limited data on 23 domestic well water supplies. Eighteen of the houses were served by deep wells, and in those cases in which a member of the household was interviewed, the water was reported to be satisfactory. Five dwellings were served by shallow wells. Shallow well waters were used for drinking and culinary purposes at three houses, at two of which they were reported to have had taste and odor, and at one to be satisfactory.

It is noted that Brighton, a city of somewhat more than 10,000 population, obtains water from the shallow aquifer some 5 to 6 miles downstream from the area of known ground water contamination. It appears essential that consideration be given to the possible future entrance of the contaminated water into the Brighton wells.

PROTECTIVE AND REMEDIAL MEASURES

The first concern is the early detection of the contaminated domestic water supplies, consumption of which might result in injury to health. This requires establishing a monitoring program. Next in importance is the prevention of any additional contamination of the ground water, either from sludge accumulations in Reservoir A, wastes retained in holding Reservoir F, or future wastes. Finally, consideration should be given to measures which might alleviate existing ground water contamination.

MONITORING PROGRAM

Immediate steps should be taken to initiate a monitoring program to determine the present extent of the contaminated ground water area and the course and rate at which the contamination is traveling. It is believed conductivity tests or chloride determinations should be adequate for this purpose.

It is recommended that until additional information becomes available a chloride concentration of 200 mg/l be considered as presumptive evidence of contamination, and that all waters of higher concentration be considered "unsafe for drinking or culinary purposes." It is emphasized that the presumed safety of the water is not based on its content of chlorides, but that chloride concentration of 200 mg/l is evidence that 3 percent to 5 percent of the water originated from the highly contaminated area underlying the Rocky Mountain Arsenal property, and that such water may contain toxic substances. It should be recognized that this chloride concentration, considered to indicate pollution, may be adjusted in either direction as more information becomes available.

All domestic water supplies from both shallow and deep wells drawing water from within the contaminated area should be checked for conductivity or chlorides, and all such waters showing conductivity or chloride concentrations in excess of 200 mg/l should be examined to determine whether chlorates, 2, 4-D or other contaminants exceed the maximum permissible limits for potable water.

Exploratory studies should be undertaken to determine what other contaminants are likely to be present. A detailed review should be made of the waste materials likely to have been discharged since the operation of the arsenal started in 1943. Samples of the wastes in reservoir F and from a few of the more heavily contaminated wells should be evaporated and the residues examined by spectrographic analyses. Other analyses, which might prove helpful, include:

1. Phosphorus as inorganic, organic and phosphonate.
2. Chemical Oxygen demand (COD).
3. Fluoride.
4. Arsenic.

The appropriate health authorities should be kept informed concerning private domestic wells which are contaminated and the property owners of such wells should be notified in writing that the water is "Unsafe for Drinking and Culinary Use."

This monitoring should be a continuing or periodic project. Certain domestic wells, particularly the shallow wells which may be in the path of advancing contaminated water, should be checked from time to time. The selection of these domestic wells and the time intervals at which they should be sampled depend on the results of the initial monitoring study.

Periodic studies should also be made to determine the course and rate of travel of the contaminated water. Selected shallow irrigation or domestic wells may be used for this purpose.

Efforts should be made to determine the extent, if any, that the contaminated ground water rises to the surface to discharge into the South Platte River.

The State Department of Health has established a monitoring program using water samples from 5 wells located along the east-west section line, 2 miles south of Brighton. Due to problems of sampling, the wells are not in all cases those originally selected after consultation with the U. S. Geological Survey. It is considered desirable that the U. S. Geological Survey be again consulted regarding the adequacy of the sampling wells for detection of contamination which might eventually affect the Brighton water supply. It may be that selection of some additional wells, or even the drilling of special sampling wells, is indicated.

Analyses of waters sampled May 22-25, 1959, from these 5 monitoring wells indicate these waters were free from contamination at that time. It is estimated that the underground water flows at a rate of approximately a mile per year. Thus, contamination should be detectable in samples from properly selected monitoring wells approximately two years prior to the contamination, if any, of the wells serving Brighton.

Although there is no evidence of leakage from the asphalt-lined waste evaporation pond, this waste is highly concentrated and even small amounts of leakage may contribute substantial amounts of contamination of the ground water. Continuing studies should be made in the attempt to detect such leakage should it occur. Possible methods include analyses of water from nearby

test wells, studies of ground water levels in the area and the balancing of waste discharges against net evaporation.

DEFECTIVE DEEP WELLS

Evidence is presented in the U. S. Geological Survey report that there are a few deep wells which provide an interconnection between the shallow and artesian aquifers. Although under normal conditions the artesian water may be under such pressure as to exclude entrance of shallow water into the artesian aquifer, good engineering practice requires that such wells be located and plugged.

SLUDGE DEPOSITS IN RESERVOIR A

Excavation into the bottom of Reservoir A, which received waste from the Rocky Mountain Arsenal Operations from 1943-1955, revealed approximately 18 inches or more of a sticky, odoriferous sludge. Moreover, water was standing in a portion of this reservoir and there was evidence of surface drainage into it.

Analyses should be made of the sludge from this deposit to determine whether it continues to contaminate water percolating through it. If it should be found to be an important source of contamination of ground water, corrective measures should be effected.

Such a source of contamination can be eliminated by preventing water from coming into contact with the sludge. Intelligent selection of the methods to be used requires information on the relative elevations of the sludge layer and water table. If the sludge layer is below the water table the only practical

solution would be physical removal of the sludge. It might be hauled to a remote spot or placed nearby in a compact pile on high ground not receiving surface drainage. The sludge pile should be covered with a relatively impervious soil or other material to prevent rain water or other precipitation from seeping into and through the sludge.

If the sludge layer is above the water table, the elimination of surface drainage into the low spots in the bed of pond A would be helpful. It is also possible that such surface drainage as could not be eliminated could be collected at low spots in water-tight tanks and prevented from coming into contact with the sludge by either pumping it to a location draining away from the pond, or injecting it through a water-tight casing into the ground water.

PUMPING OF SELECTED WELLS

Consideration might be given to removal of contaminated ground water by pumping selected or specially constructed wells in areas of relatively high contamination. This assumes discharge of the contaminated well waters to The South Platte River during times of sufficient flow to provide adequate dilution. Possible advantages include alleviation of ground water contamination and channelization of the contaminated ground water so as to restrict the contaminated area. Such operations might be particularly helpful in preventing or reducing the possible contamination of the Brighton wells. This would require consideration of ground water rights.

PROPOSED DEEP INJECTION WELL

Currently, the disposal of waste through deep well injection into the Lakota sandstone some 9,000 feet underground is under consideration. The Ralph M. Parsons Company, Los Angeles, included deep well injection along with other investigated methods of treating and handling wastes. At that time they recommended against deep well injection. Since then, efforts made to reduce the volume of wastes have resulted in a reported reduction from 500 to 100 gpm. (The instantaneous flow entering the holding pond was roughly estimated at 200 gpm by the writer on August 14, 1959). Mr. Thad McLaughlin, Geologist, U. S. Geological Survey, who formerly expressed an opinion that deep well injection would not be a satisfactory solution, recently informed the writer that he thought it feasible to inject the flow of approximately 100 gpm through a deep well. It should be noted that rigid control of the amount of waste process water might be required and that the capacity of the injection well would probably be exceeded in case of mobilization.

The approval of the State Department of Health should be secured prior to drilling such a well. Care must be taken in the design and construction to prevent leakage of the injected waste waters into potable water aquifers through which the well penetrates, and means must be provided to detect such leakage should it occur.

No attempt has been made in this report to determine whether such a well will prove successful, whether pretreatment of wastes may be required to maintain their continued acceptance into the strata, or whether such a procedure is the most economical long-term solution of waste disposal.

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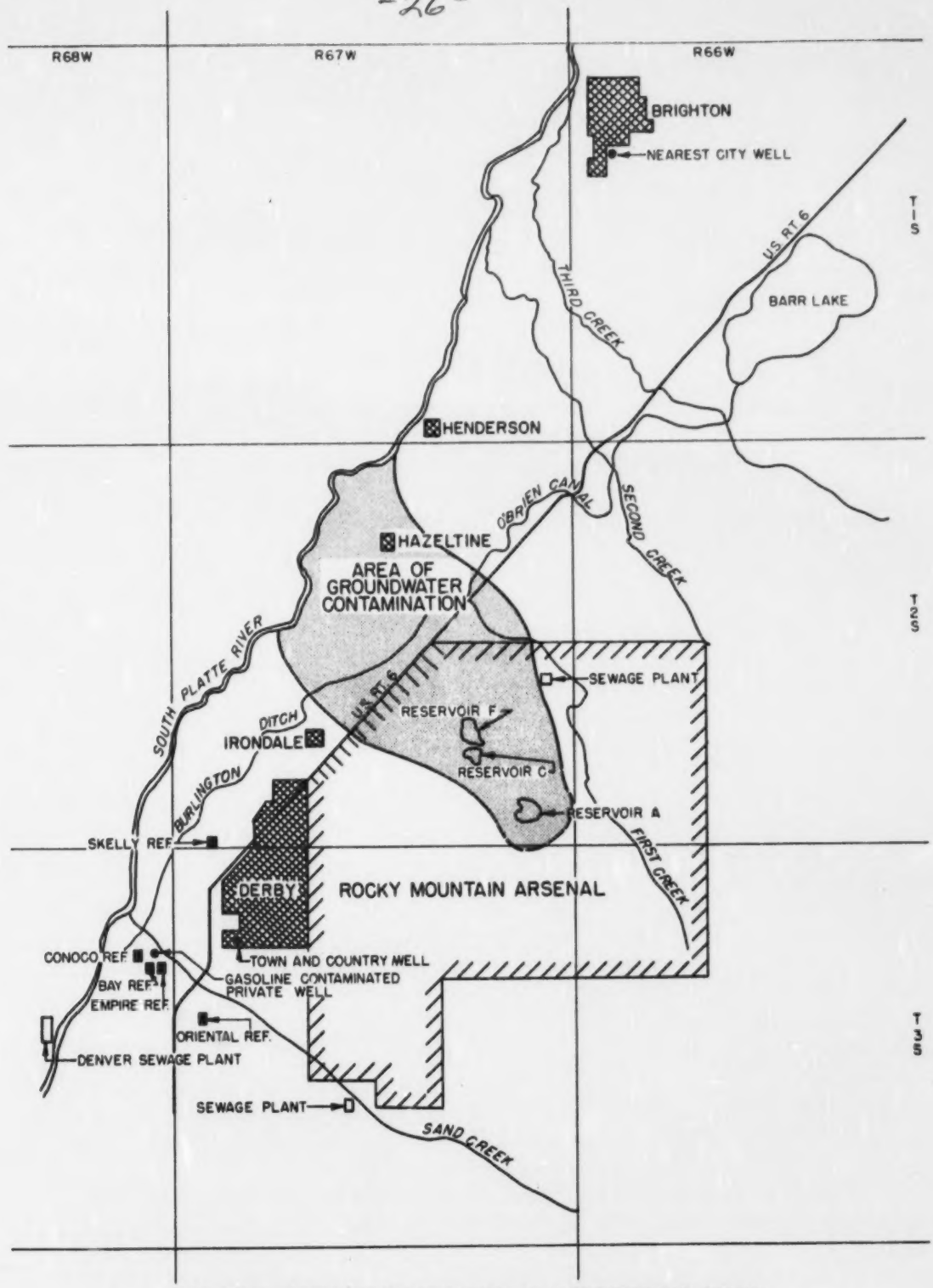
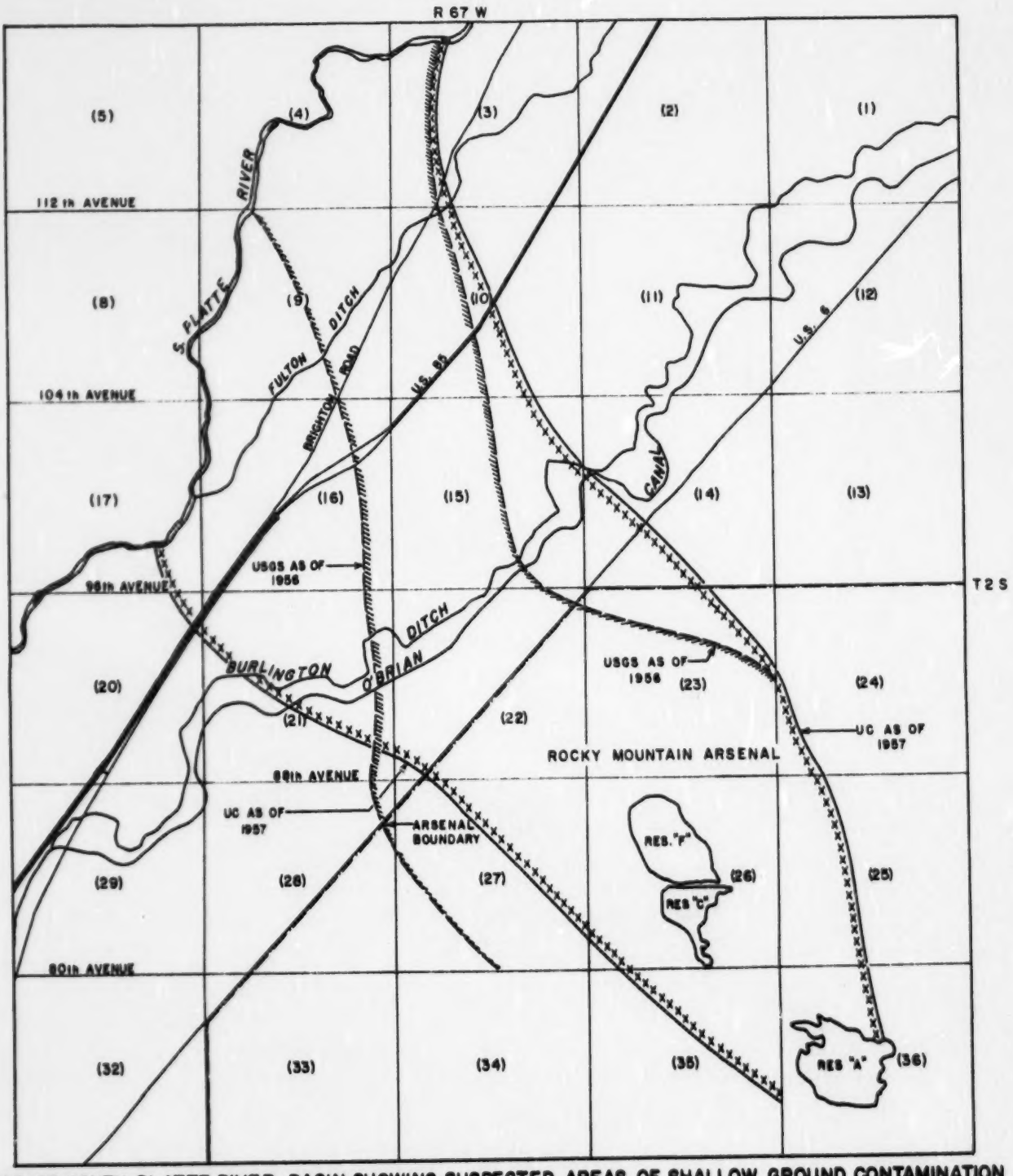


MAP OF AREA INVESTIGATED IN CONNECTION WITH CONTAMINATION OF SHALLOW GROUND WATER

FIGURE 1



MAP OF SOUTH PLATTE RIVER BASIN SHOWING SUSPECTED AREAS OF SHALLOW GROUND CONTAMINATION AS OF 1956 AND 1957

uuuuuuuuu Boundary of contaminated area as indicated by 200mg/l isochloride concentration, 1956, USGS Report
xxxxxxxx Boundary of contaminated area as indicated by Phytotoxin characteristics, 1957, Univ. of Colorado Studies

FIGURE 2